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Editorial

Becoming an intentional agent: Introduction to the special issue

Our behavior is commonly much more driven by our intentions and goals than by particular stimuli or situations. That is, we are used to experiencing and interpreting goal-directed actions of others, and carrying out goal-directed actions by ourselves. This special issue addresses the question of how we can do this. How can we intend to reach a particular goal, translate this goal into appropriate ways to move our body, and how do we understand that other people do the same?

Cognitive developmental approaches to the perception and production of intentional action have yielded major insights during the last two decades or so. However, there is room for improvement with respect to the communication between developmental studies, general cognitive or neurocognitive models and approaches to action control. This issue aims to provide a representative overview of both empirical and theoretical achievements within the developmental study of action perception and production for a broader cognitive and neurocognitive readership.

The developmental process of understanding self and others as intentional agents is by no means a new question. To what extent one can have direct access to his or her intentional states, the ways in which one can distinguish self from the external world, how one's own experience leads to inferences about others' mental states are just some of the questions that have been discussed by the early and current thinkers of philosophy of mind, and that are inherently related to the issue of what it takes to become an intentional agent. Current developmental theoretical accounts on the emergence of understanding intentional actions are influenced by the different views philosophers have towards these issues (e.g., Davidson, 1963; Dennett, 1991; Fodor, 1987; Searle, 1983), and also reflect current cognitive models of the representation of intentional action (e.g., Hommel, Müsseler, Aschersleben, & Prinz, 2001; James, 1890; Jeannerod, 1999; Prinz, 1997).

A fully developed form of understanding of self and others as intentional agents implies the ability to interpret and predict one's own and others' actions in terms of intentional mental states such as desires and beliefs ('theory of mind'). The origins and the developmental unfolding of this understanding and the possible mechanisms that are responsible for its emergence are central issues in cognitive infancy research. Recent methodological and theoretical breakthroughs have led to a rapid growth of our insights into these

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questions. Before inviting the reader to enjoy the contributions, we will give a short overview of the cognitive developmental research on the topic.

Developmental research on the emergence of understanding and the ability to produce intentional actions can be traced back to Piaget's work (1952). He claimed that infants at first cannot distinguish whether stimuli belong to self or environment, and that they, therefore, do not understand the causal influence of their actions on the external world. However, more recent research using creative experimental designs has demonstrated that voluntary action control is to some extent already present in very young infants. For example, 2-month-old infants can modulate their oral activity (sucking on a dummy pacifier) to increase the optical clarity of a film presented to them or to control the pitch variation of a sound (Rochat & Striano, 1999), and they can modify their body posture and the position of their head to compensate for a loss of balance (Butterworth & Hicks, 1977). These findings suggest that infants can make an active use of the causal relationship between their movements and the perceptual consequences that these movements evoke. Furthermore, 2–6 month-old infants can monitor and control their kicking and reaching behavior by taking response–stimulus contingencies and other environmental constraints into account (e.g., Rochat & Morgan, 1995; von Hofsten & Fazel-Zandy, 1984; Watson, 1972). Gergely and Watson (1999) hypothesized that infants possess an innate "contingency detection module" that seeks out certain response contingent stimulation. In the first 2–3 months, the module biases infants to explore perfect contingencies between responses and stimuli and thus assists in the development of a sense of self and agency in the infant. Around 3 months, the module shifts to prefer high but imperfect degrees of contingencies that are typically provided by social partners and thus orient infants towards discovering the social world.

Recent studies have also documented infant's sensitivity and early abilities in social interactions with caregivers. Meltzoff and his colleagues showed that neonates can imitate tongue propulsion and that somewhat older infants can delay their imitative action and may even be able to make corrections in order to match their own action with a modeled one (e.g., Meltzoff & Moore, 1977, 1997). The authors proposed that the early ability to imitate is not automatic or reflex-based, but under the infant's control from the start and mediated by an active cross-modal matching. Very young infants were also observed to take part in contingent affective interactions with their caregivers and to react with dissatisfaction when the caregiver's reaction abruptly stops being contingent with the infant (Murray & Trevarthen, 1985). Theories are strongly divided on whether these early affective and imitative interactions can be interpreted as an innate ability to introspectively access and differentiate one's own intentional states and recognize similar states of other's mind (Meltzoff & Moore, 1997; Trevarthen, 1993), or whether they should be considered only as reflecting innate social reactivity to human faces and voices accompanied with sensitivity to contingent relations. According to the latter view, the function of these early interactions is, therefore, not to share each others mind states, but to establish proximity to the caregiver, regulate affective states and to maintain an environment in which the infant can learn about dispositional displays of others (Gergely & Watson, 1999).

In the second half of the first year, infants reach a further step in becoming intentional agents by demonstrating a new level of understanding and producing goal-directed actions. Developmental progress in means-end coordination around 9 months indicates that infants can differentiate between means and goals and that they are able to choose the appropriate means to achieve their goals (Piaget, 1952; Willatts, 1999). Extensive research

exists on the role of the development of executive processes in infants' performance on means-end tasks, such as the increasing ability to inhibit and control stimulus-induced action tendencies (e.g., Hughes & Russell, 1993). Maturation of specific brain areas, the frontal lobe in particular, has also been hypothesized to mediate the development of this skill (Diamond, 1991).

The evidence for the ability to interpret actions of others as goal-directed came from recent studies relying on looking time measurements. It has been demonstrated that infants as young as 6 months show sensitivity to the end-states of observed events and can infer an agent's "preference" to act upon one object over another (Biro & Leslie, in press; Kiraly, Jovanovic, Prinz, Aschersleben, & Gergely, 2003; Luo & Baillargeon, 2005; Woodward, 1998, 1999). However, there is an ongoing debate among researchers on the scope of early goal-directed action interpretation. Controversial issues include the type of agent (human vs. inanimate) and the type of action (only actions that are familiar to the infants vs. any action as long as it exhibits certain behavioral cues indicating goal-directedness) that infants initially consider as goal-directed. By 9–12 months, infants can interpret goal-directed actions at a rather sophisticated level: in a new situation they can predict the most efficient action available to the agent to achieve its goal (Gergely, Nádasdy, Csibra, & Biro, 1995), they can infer unseen goal-states as well as unseen aspects of the environment that constrains the action (Csibra, Biro, Koós, & Gergely, 2003), and they can comprehend the causal constraints that link a sub-goal to an overarching goal (Woodward & Sommerville, 2000). Based on this evidence, Csibra and Gergely (1998) proposed that infants interpret goal-directed actions teleologically. The authors hypothesize that this teleological stance generates reality-based representations of goal-directed action that are not yet mentalistic.

Around 9 months, infants also start to engage in new kind of interactive behaviors with their caregivers that indicate goal-directed activities. These behaviors involve joint attention such as pointing to objects, social referencing (using the caretaker's facial emotion expressions to evaluate an ambiguous situation), showing objects and gaze alteration between object and caregiver. Imitation studies using elegant designs have demonstrated further sophistication in infants' understanding of goal-directed actions in the second year. By 14 months of age, infants can distinguish between accidental and intentional actions (Carpenter, Akhtar, & Tomasello, 1998) and 18-month-old infants are able to both infer and imitate the intended goal of the model's action even if the model repeatedly fails to achieve this goal (Meltzoff, 1995). Furthermore, infants can imitate in a rational, cost-efficient way: they evaluate the model's situational constraints and they imitate the model's action only if they consider it to be the most rational alternative (Gergely, Bekkering, & Király, 2002). Finally, in a very recent study using the violation-of-expectations paradigm, Onishi and Baillargeon (2005) have shown that 15-month-old infants are able to infer an agent's goal-directed action by attributing a false belief to the agent about the state of reality. While most of the new evidence mentioned above considerably changed our earlier view on the level of sophistication of infants' representation of intentional actions, this latter finding suggests something truly remarkable: the presence of mentalistic understanding of intentional action in infancy at a level that was traditionally believed to develop only in 3–4-year-olds.

Several theoretical proposals have been put forward to account for the nature of infants' ability to understand and produce intentional actions. These theories differ greatly in the mechanisms that they assume to be responsible (e.g., domain-specific modular systems: Leslie, 1994), teleological action interpretational system (Csibra & Gergely, 1998),

an identification-based drive to imitate or simulate others' intentions (Meltzoff & Moore, 1997; Tomasello, 1999), or action-effect associations (Elsner & Hommel, 2001). These accounts also hold different views on the role that experience and learning play in understanding intentions, on whether understanding self has primacy over understanding others, and on the type of evidence for goal-directed action interpretation and production that implies the ability to represent causal mental states.

The first four papers in the current special issue tap right into these theoretical questions about the nature of the development of intentional action. Rochat (2007) takes a 'social externalist' view and argues that early reciprocal social interactions around 2 months, that allow perspective taking, are the primary mechanism for the emergence of infants' understanding of intentional actions. His main claim is that infants first learn to become an intentional agent, and perceive others as such, in communicative situations and then generalize this learning to their own or other's actions with physical objects. Meltzoff (2007) elaborates on his 'simulationist' model that claims that infants' innate ability to recognize shared motor behavior and to project their own experiences to observed actors is the basis for intentional understanding. He discusses new and intriguing studies on the imitation of intended but failed goals of others in the first 2 years. Elsner's paper (2007) provides us with a fresh view by systematically examining the role of two components of goal-directed actions in infants' imitative skills: movements and action-effects. She argues that the ability to encode and remember these components contributes to age-related changes in infants' imitation skills. She suggests that the advantage that infants generally get from full demonstration (movement and action-effect) might be best explained by applying the two-stage action control model of adults to the development of goal-directed actions in infancy. Gergely Csibra and György Gergely (2007) take a 'functional stance' in their insightful analysis of the computational problems of goal-directed action representation. They examine inverse problems involved in inferences that have to be drawn to fulfill two main functions of our tendency to interpret actions in terms of goals. These functions – they argue – are on-line action prediction and social learning of novel means and novel goals. They then contrast three distinct mechanisms (action-effect association, simulation procedures and teleological reasoning) on how well they can serve these functions. Csibra and Gergely conclude that action-effect association and simulation can serve on-line action prediction, but social learning requires teleological reasoning.

The second group of four papers reports on exciting empirical studies that not only add to our growing knowledge of the developmental course of understanding and producing intentional actions, but also have significant implications for the theoretical accounts. Song and Baillargeon (2007) use the violation-of-expectation paradigm to show that 9-month-old infants are able to attribute preferences to agents to perform certain actions. An interesting discussion follows the study on whether this and similar evidence implies that infants are guided by dispositions (some enduring properties attributed to the agent) or rather by some general goals. Onishi, Baillargeon, and Leslie (2007) report the first study on 15-month-old infants' striking ability to detect violation in the consistency of pretend scenarios. Making sense of pretense actions is considered to be a major step towards a mature understanding of others as intentional agents because it involves representing intentional actions that are not consistent with the actual state of the world. This is also the case with the understanding that someone is acting on a false belief. Their study therefore corroborates the earlier study by Onishi and Baillargeon (2005) that suggested the presence of false belief attribution at the same age. This finding fits in with those accounts

that postulate early presence of psychological-reasoning systems instead of long learning processes that lead to false belief concept only in pre-school children. Rapid technical advances in neuropsychological measurements have allowed researchers to investigate social cognition in infants' developing brain. Reid, Csibra, Belsky, and Johnson (2007) look at the neural correlates of the perception of goal-directed action in 8 months old. They find that the left frontal regions of the brain are sensitive to the disruption of observed goal-directed actions. Based on their finding they suggest that infants are capable of processing goal-directed actions before they have the ability to perform the actions themselves. This challenges theoretical accounts that claim simulation processes are at the heart of the development of intentional action interpretation. Finally, Eenshuistra, Ridderinkhof, Weidema, and van der Molen (2007) investigated the development of the ability to suppress unwanted action tendencies. They compared the performance of 8-year- and 12-year-old children and young adults in the anti-saccade task, which requires subjects to suppress stimulus-induced eye movements towards visual stimuli that appear with an abrupt onset. Unsurprisingly, children had more difficulties to suppress stimulus-directed actions than adults, presumably due to the insufficient maturation of the frontal cortex, which is known to play a major role in action control. Interestingly, however, manipulations that should have facilitated the direct inhibition of stimulus-triggered saccadic actions (such as providing a visual "anchor" while the stimulus is presented) affected young and old subjects equally. In stark contrast, loading working memory undermined inhibitory control in the 8-year-olds and led to a very substantial increase of stimulus-triggered saccades. This suggests that working memory plays a major role in action control and that developmental deficits in working memory capacity might explain why younger children find it so difficult to resist temptation.

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References

Biro, S., & Leslie, A. M. (in press). Infants' perception of goal-directed actions. Development through cues-based bootstrapping. *Developmental Science*.

Butterworth, G., & Hicks, L. (1977). Visual proprioception and postural stability in infancy: A developmental study. *Perception, 6*, 255–262.

Carpenter, M., Akhtar, N., & Tomasello, M. (1998). Fourteen- through 18-month-old infants differentially imitate intentional and accidental actions. *Infant Behavior and Development, 21*, 315–330.

Csibra, G., Biro, S., Koós, O., & Gergely, G. (2003). One year old infants use teleological representation of actions productively. *Cognitive Science, 27*(1), 111–133.

Csibra, G., & Gergely, G. (1998). The teleological origins of mentalistic action explanations: A developmental hypothesis. *Developmental Science, 1*, 255–259.

Csibra, G., & Gergely, G. (2007). 'Obsessed with goals': Functions and mechanisms of teleological interpretation of actions in humans. *Acta Psychologica, 124*(1), 60–78.

Davidson, D. (1963). Actions, reasons, and causes. *Journal of Philosophy, 60*, 685–700.

Dennett, D. C. (1991). *Consciousness explained*. Boston: Little, Brown and Co.

Diamond, A. (1991). Guidelines for the study of brain-behaviour relationship during development. In H. S. Levin, H. M. Eisenberg, & A. L. Benton (Eds.), *Frontal lobe function and dysfunction* (pp. 339–378). Oxford: Oxford University Press.

Eenshuistra, R. M., Ridderinkhof, K. R., Weidema, M. A., & van der Molen, M. W. (2007). Developmental changes in oculomotor control and working-memory efficiency. *Acta Psychologica, 124*(1), 139–158.

Elsner, B., & Hommel, B. (2001). Effect anticipation and action control. *Journal of Experimental Psychology: Human Perception and Performance, 27*, 229–240.

Elsner, B. (2007). Infants' imitation of goal-directed actions: The role of movements and action effects. *Acta Psychologica, 124*(1), 44–59.

Fodor, J. A. (1987). *Psychosemantics: The problem of meaning in the philosophy of mind*. Cambridge, MA: MIT Press.

Gergely, G., Bekkering, H., & Király, I. (2002). Rational imitation in preverbal infants. *Nature, 415*, 755.

Gergely, G., Nádasdy, Z., Csibra, G., & Biro, S. (1995). Taking the intentional stance at 12 months of age. *Cognition, 56*, 165–193.

Gergely, G., & Watson, J. S. (1999). Early social-emotional development: Contingency perception and the social-biofeedback model. In P. Rochat (Ed.), *Early social cognition* (pp. 101–136). Hillsdale: Erlbaum Publishers.

Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (2001). The theory of event coding (TEC): A framework for perception and action planning. *Behavioral and Brain Sciences, 24*, 849–878.

Hughes, C., & Russell, J. (1993). Autistic children's difficulty with mental disengagement from an object: Implications for theories of autism. *Developmental Psychology, 29*, 498–510.

James, W. (1890). *The principles of psychology* (Vol. 2). New York: Dover Publications.

Jeannerod, M. (1999). To act or not to act: Perspectives on the representation of actions. *Quarterly Journal of Experimental Psychology, 52A*(1), 1–29.

Kiraly, I., Jovanovic, B., Prinz, W., Aschersleben, G., & Gergely, G. (2003). The early origins of goal attribution in infancy. *Consciousness and Cognition, 12*, 752–769.

Leslie, A. M. (1994). ToMM, ToBy, and agency: Core architecture and domain specificity. In L. A. Hirschfeld & S. A. Gelman (Eds.), *Mapping the mind: Domain specificity in cognition and culture*. Cambridge University Press.

Luo, Y., & Baillargeon, R. (2005). Can a self-propelled box have a goal? Psychological reasoning in 5-month-old infants. *Psychological Science, 16*(8).

Meltzoff, A. N. (1995). Understanding of the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology, 31*, 838–850.

Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science, 198*, 75–78.

Meltzoff, A. N., & Moore, M. K. (1997). Explaining facial imitation: A theoretical model. *Early Development and Parenting, 6*, 179–192.

Meltzoff, A. N. (2007). The 'like me' framework for recognizing and becoming an intentional agent. *Acta Psychologica, 124*(1), 26–43.

Murray, L., & Trevarthen, C. (1985). Emotional regulation of interactions between two-month-olds and their mothers. In T. M. Field & N. A. Fox (Eds.), *Social perception in infants* (pp. 177–198). Norwood, NJ: Ablex.

Onishi, K., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science, 308*, 255–258.

Onishi, K. H., Baillargeon, R., & Leslie, A. M. (2007). 15-month-old infants detect violations in pretend scenarios. *Acta Psychologica, 124*(1), 106–128.

Piaget, J. (1952). *The origins of intelligence in children (M. Cook, Trans.)*. New York: International Universities Press.

Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology, 9*, 129–154.

Reid, V. M., Csibra, G., Belsky, J., & Johnson, M. H. (2007). Neural correlates of the perception of goal-directed action in infants. *Acta Psychologica, 124*(1), 129–138.

Rochat, P., & Morgan, R. (1995). Spatial determinants in the perception of self-produced leg movements in 3- to 5-month-old infants. *Developmental Psychology, 31*, 626–636.

Rochat, P., & Striano, T. (1999). Emerging self-exploration by 2 month-old infants. *Developmental Science, 2*(2), 206–218.

Rochat, P. (2007). Intentional action arises from early reciprocal exchanges. *Acta Psychologica, 124*(1), 8–25.

Searle, J. (1983). *Intentionality*. Cambridge: Cambridge University Press.

Song, H., & Baillargeon, R. (2007). Can 9.5-month-old infants attribute to an agent a disposition to perform a particular action on objects? *Acta Psychologica, 124*(1), 79–105.

Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.

Trevarthen, C. (1993). The self born in intersubjectivity: An infant communicating. In U. Neisser (Ed.), *The perceived self* (pp. 121–173). New York: Cambridge University Press.

von Hofsten, C., & Fazel-Zandy, S. (1984). Development of visually guided hand orientation in reaching. *Journal of Experimental Child Psychology, 38*(2), 208–219.
Watson, J. S. (1972). Smiling, cooing, and the game. *Merrill–Palmer Quarterly, 18*, 323–339.
Willatts, P. (1999). Development of means-end behaviour in young infants: Pulling a support to retrieve a distant object. *Developmental Psychology, 35*(3), 651–667.
Woodward, A. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition, 69*, 1–34.
Woodward, A. (1999). Infants' ability to distinguish between purposeful and non-purposeful behaviors. *Infant Behavior and Development, 22*(2), 145–160.
Woodward, A., & Sommerville, J. A. (2000). Twelve-month-old infants interpret action in context. *Psychological Science, 11*(1), 73–77.

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